Status and preliminary results of the ANAIS experiment at Canfranc

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ANAIS (Annual Modulation with NaI's) is an experiment planned to investigate seasonal modulation effects in the signal of galactic WIMPs using up to 107 kg of NaI(Tl) in the Canfranc Underground Laboratory (Spain). A prototype using one single crystal (10.7 kg) is being developed before the installation of the complete experiment; the first results presented here show an average background level of 1.2 counts/(keV kg day) from threshold ($E_{thr} \sim 4$ keV) up to 10 keV.

1. INTRODUCTION

There is a substancial evidence to conclude that most of the matter in the Universe must be dark and that it consists mainly of cold non-baryonic particles. Weak Interacting Massive Particles (WIMPs) are favourite candidates to such non-baryonic components. A convicing proof of the detection WIMPs, which are supposedly filling the galactic halo, would be to find unique signatures in the data, like seasonal asymmetries. ANAIS (Annual Modulation with NaI's) is a large mass experiment intended to investigate the annual modulation effect which would be produced in the signal of galactic WIMPs due to the variations in the relative velocity between the Earth and the halo [1]. It will be installed in the Canfranc Underground Laboratory, located in an old railway tunnel in the Spanish Pyrenees with an overburden of 2450 m.w.e., using up to 10 NaI(Tl) hexagonal crystals (10.7 kg each) as an improved scaled-up version of a previuos experiment [2]. Before setting-up the whole experiment, a prototype is being developed in Canfranc in an attempt to obtain the best energy threshold and lowest radioactive background in the low energy region (2 to 50 keV), as well as to check the stability of the environmental conditions which influence on the detector response.

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2. THE ANAIS PROTOTYPE

One single detector has been used in the ANAIS prototype; it consists of a NaI(Tl) crystal encapsulated inside 0.5-mm-thick stainless steel and coupled to a PMT through a quartz window. Some components of the photomultiplier have been removed because of their radioimpurities. The scintillator has been placed in a shielding consisting of 10 cm of archaeological lead (of less than 9 mBq/kg of ^{210}Pb) followed by 20 cm of low activity lead, a sealed box in PVC (maintained at overpressure to prevent the intrusion of radon), 2-mm-thick cadmium sheets, and finally, 40 cm of polyethylene and tanks of borated water. An active veto made of plastic scintillators is covering the set-up.

The data acquisition system, based on standard NIM and CAMAC electronics, has two different parts following the two output signals implemented from the PMT; the fast signal is recorded using a digital oscilloscope while the slow signal is routed through a linear amplifier and analog-to-digital converters controlled by a PC through parallel interfaces, to register the energy of events up to ~ 1.7 MeV.

Parameters of the pulses used to reject the noise produced by PMT in the various previous NaI experiments are the mean amplitude [3], a ratio of area portions [4], etc. In the present work the filtering of noise uses the squared deviation of the digitalized pulse from the well-known theore-

tical shape of a scintillation event of the same area. To reject the noise, a safe cut at 3σ from the center of the gaussian distribution of this parameter for calibration events from 4 to 10 keV has been used.

By comparing the data recorded from December 2000 to August 2001 with the Monte Carlo simulations, it was possible to identify the main sources of background in the region of interest. The ^{210}Pb 46.5 keV line as well as a peak due to the escape of X-rays of I at $\sim$ 16 keV seen in the spectrum, may be caused by the presence of radioimpurities in the stainless steel can and/or in the PMT. The area of the 1460.8 keV peak is compatible with an activity of 15 mBq/kg from ^{40}K in the NaI crystal; these impurities produce an almost flat background in the low energy region due to their beta emission. A comparison between the spectra recorded with and without the neutron shielding does not show noticeable differences.

A pulse shape analysis has been carried out with the purpose of investigate the possible appearance of the so-called "anomalous" or "bump" events found in other NaI experiments [5,6]. No evidence of such anomaly has been found in the distributions for background events, neither following the method of the UKDMC (fitting integrated pulses to calculate the decay time constant) nor using other parameters (like the first momemtum of the pulse).

Monitoring and stabilisation control of the environmental conditions (radon levels, N_2 flux, temperature in the laboratory and in the inner enceinte, photomultiplier working voltage, ...) is underway. Using the data of the prototype, collected along almost 6000 hours, the stability of some parameters has been checked. The fluctuations of the ADC channels for the different peaks used to perform the energy calibration range from 1 to 1.5 %. With respect to the counting rates, the gaussian distributions of the deviations from the mean values have a sigma of 1.27 for the rate integrated above 6 keV and 1.47 for the rate above 100 keV.

3. FIRST RESULTS

The results presented here correspond to an exposure of 1225.4 kg×day. Fig. 1 shows the raw spectrum and the spectrum after the noise rejection up to 100 keV. The energy threshold is of $\sim$ 4 keV and the background level registered from the threshold up to 10 keV is about 1.2 counts/(keV kg day).

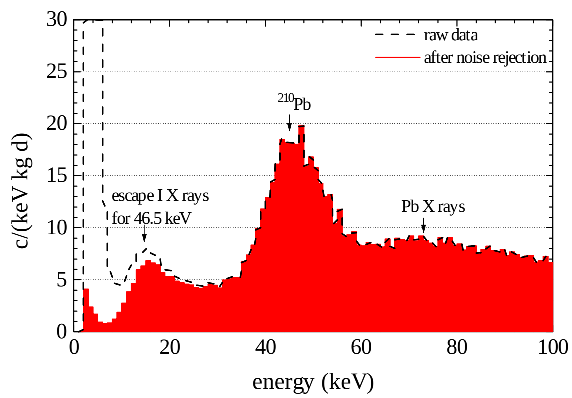

Figure 1. Low-energy region of the observed spectrum in the prototype of ANAIS before and after the noise rejection.

We have used this region to derive the corresponding limits for the WIMP-nucleon cross sections. The galactic halo is supposed to be isotropic, isothermal and non-rotating, assuming a density of ρ=0.3 GeV/cm^3, a Maxwellian velocity distribution with v_{rms}=270 km/s (with an upper cut corresponding to an escape velocity of 650 km/s) and a relative Earth-halo velocity of v_r=230 km/s. The Helm parameterization [7] is used for the coherent form factor, while the approximation from [8] is considered for the SD case. Spin factors $(\lambda_p J(J+1))$ 0.089 and 0.126 are assumed for Na and I respectively. Fig. 2 shows, in addition to the limits

derived from the prototype results (solid lines), the estimates considering a flat background of 1 count/(keV kg day) from 2 to 8 keV after an exposure of 107 kg×y both for raw data (dotted lines) and assuming PSD (dashed lines). The plots show the contour lines for each nucleus, Na and from I, as well as the NaI case. That is shown both for SI scalar interactions and SD WIMP-proton interactions. It should be noted that for SI interactions and using PSD techniques, ANAIS will be able to explore the region of WIMPs singled out by the possible annual modulation effect reported by the DAMA collaboration [9].

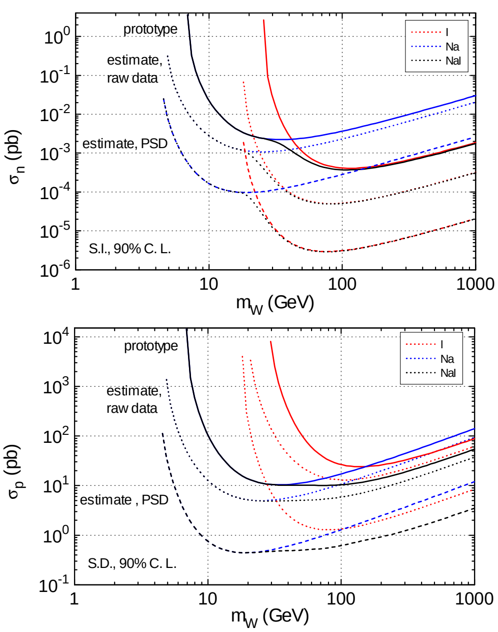

Figure 2. Exclusion plots derived for SI (top) and SD (bottom) interactions from the prototype (solid line) and expected for the whole experiment with (dashed line) and without (dotted line) PSD techniques.

4. FUTURE PROSPECTS

The next steps in the development of the prototype of ANAIS, according to these first results, are the removal of the present PMT and the steel can and to install, instead, two ultra-low background PMT and a 1-cm-thick teflon enclosure filled with special mineral oil, as in the NAIAD experiment [10]. A program of measurements to select high radiopurity materials is in course in Canfranc, using an ultra-low background Ge detector. The program includes the removal of components when neccesary to reduce, as much as possible, the various sources of background, to diminish the noise by using anticoincidence readout (lowering so also the energy threshold) and improving the collection of the scintillation light.

Acknowledgements

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